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GENE-523-A110-1095
DRF # 137-0010-8
October 1995

A STRUCTURAL MARGIN EVALUATION FOR HATCH 2 INTERNAL CORE SPRAY LINES

October 1995

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1. INTRODUCTION AND SUMMARY

This report presents the results of a structural margin evaluation of the Hatch 2 core spray line at the location of a reported flaw indication identified by IVVI. The indication is 1/2" long, is located on the elbow side of the fillet weld between the collar and the pipe in the region of the downcomer coupling and is being treated as a crack. The fact that the indication is below the toe of the fillet weld and in the heat affected zone (HAZ) of the weld suggests that the possible flaw, if it is a crack, may not have started from the crevice on the inside. It is more likely that a crack would initiate from the weld HAZ on the outside of the pipe.

In order to address potential safety concerns related to this possible cracking at Hatch 2, GE Nuclear Energy has performed a preliminary evaluation to determine the safety significance of through-wall cracks having the same orientation and location as the observed indication.

The technical basis to support the continued structural integrity of the Hatch 2 core spray lines for all normal and injection conditions with a postulated crack is provided.

1.1 STRUCTURAL ANALYSIS

The structural analysis, described in Section 2, examines whether the integrity of the core spray piping will be maintained in the presence of the observed indication.

1.2 CONCLUSIONS

A structural evaluation of the Hatch 2 core spray line has been performed to determine the impact on plant operation with a postulated circumferential crack near the downcomer coupling. Based on this analysis, it is concluded that Hatch 2 can safely operate with up to a 263° circumferential crack and that no operational changes or restrictions are required at this time.

2. CORE SPRAY PIPE STRUCTURAL INTEGRITY

The structural integrity aspects of the core spray piping were reviewed to assess the impact a crack could have on the structural integrity of the piping. Structural analyses were performed to determine the primary stresses in the piping. Although there is not enough information to definitively classify the flaw in the core spray line, it is assumed to be a crack due to an Intergranular Stress Corrosion Cracking (IGSCC) mechanism.

2.1 STRUCTURAL INTEGRITY

2.1.1 Summary

All primary stresses expected during normal reactor operation were found to be small compared to the yield strength of the material. Therefore, it is reasonable to conclude that the normal operating loads by themselves do not result in stresses which are sufficient to cause IGSCC initiation. The addition of secondary stresses, thermal expansion, and weld residual stresses coupled with local cold work, could result in stresses exceeding the initiation threshold.

Once initiated, the stresses relax as the crack grows, and the compliance (or flexibility) of the pipe increases. Studies show that when the crack reaches 180° of the circumference, the compliance is reduced sufficiently to relieve almost all of the displacement controlled stresses. Therefore, crack growth is expected to be negligible or at virtual arrest once reaching 180°. In order to determine the integrity of the core spray line with a crack, a crack arrest evaluation was performed. Stresses due to pipe restraint are included in this evaluation.

Based upon a review of these stresses, it is concluded that the structural integrity of the core spray piping including the crack will be maintained during core spray injection. The stresses considered include those due to downcomer flow impingement loads, seismic loading, pressure, and weight.

2.1.2 Allowable Flaw Size Determination

An evaluation was performed to determine the maximum allowable circumferential through-wall flaw size in the core spray pipe. This analysis will therefore provide an assessment of the safety margin in the pipe due to primary loads such as deadweight, pressure, flow impingement and seismic.

The acceptable through-wall flaw size of the core spray line was determined utilizing the limit load formulation of References 1 and 2. To apply this methodology, the maximum primary membrane stresses in the longitudinal direction and primary bending stresses were determined for the pipe. A finite element model of the core spray pipe was developed to obtain the stresses due to deadweight, seismic and reactor vessel downcomer flow impingement on the pipe at the location of interest, and the resulting stresses were then combined with the stresses due to pressure and core spray flow loads in order to obtain the total stresses acting on the pipe. Because the primary loads are small, a conservative analysis using the highest loads (SSE seismic and upset pressure) with upset allowables was performed. Stresses due to water hammer loads were considered insignificant and neglected in this analysis since the core spray inlet valve ramps open over a period of twenty seconds upon system actuation. Additionally, the piping is full of water during actuation due to the presence of the vent hole on the top of the T-box. Previous analyses have shown that the water hammer loads in the core spray line were calculated to be less than 20 pounds of axial load on the pipe. Stresses due to thermal mismatch were also ruled insignificant based on previous GE core spray analyses.

By applying these resulting primary stresses, with a safety factor of 2.8, it was shown that the core spray pipe can tolerate a crack up to 263° through-wall at any location without incipient failure.

Analysis and Results

A finite element model was constructed using the geometry of a core spray line very similar to that of Hatch 2. Figure 1 shows the geometry of the model. The stress analysis was conducted using ANSYS computer code (Reference 3). Loads due to the weight of the pipe (including captured water in the pipe) were applied to the model along with vertical and horizontal seismic loads and reactor vessel downcomer flow impingement loads. The largest resulting stresses were used from the finite element model results. These stresses were then combined with the stresses due to pressure and core spray flow loads. The resulting total stresses are shown in Table 1 on the next page as noted above, the loads due to thermal mismatch of the core spray line and reactor vessel need not be included as they are secondary in nature.

Stress Type	Stress Magnitude (psi)
Membrane	1000
Bending	455

Table 1: Calculated Primary Stresses

The stresses shown in Table 1 were then utilized to determine the acceptable through-wall flaw size based on the methods of References 1 and 2. The acceptable flaw size was determined by requiring a suitable design margin on the critical flaw size. The critical flaw size was determined by using limit load concepts. In the limit load theory, it is assumed that a pipe with a circumferential crack is at the point of incipient failure when the net section at the crack develops a plastic hinge. Plastic flow is assumed to occur at a critical stress level, σ_f, called the flow stress of the material. For ASME Code analysis (Section XI, Appendix C), σ_f may be taken as equivalent to $3S_m$ (S_m=14.4 ksi for 304L at 550°F, Ref. 4). A safety factor of 2.8 is used on the flow stress, for an adjusted value of 15.43 ksi. This results in considerable simplification of the analysis.

Consider a circumferential crack of length, $l = 2R\alpha$, and constant depth, d, located as shown in Figure 2. In order to determine the point at which collapse occurs, it is necessary to apply the equations of equilibrium assuming that the cracked section behaves like a hinge. For this condition, the assumed stress state at the cracked section is as shown in Figure 2 where the maximum stress is the flow stress of the material, σ_f. Equilibrium of longitudinal forces and moments about the axis gives the following equations:

(For neutral axis located such that $\alpha + \beta < \pi$)

$$\beta = [(\pi - \alpha d/t) - (P_m/\sigma_f)\pi]/2$$

$$P_b = (2\sigma_f/\pi)\,(2 \sin\beta - d/t \sin\alpha)$$

where, t = pipe thickness, inches

α = crack half-angle as shown in Figure 2

β = angle that defines the location of the neutral axis

P_m = Membrane axial stress

P_b = Bending stress

Using the stresses of Table 1 and a d/t ratio of 1.0 (through-wall flaw), the allowable through-wall crack for which failure by collapse might occur is 263°.

Since the applied stresses are displacement controlled, the compliance will increase enough by the time a 180° through-wall crack develops that crack arrest is expected.

2.2 SUMMARY AND CONCLUSIONS

The potential sources of stress in the Hatch 2 core spray piping resulting from various plant conditions were reviewed. The postulated cracking mechanism is assumed to be IGSCC.

Due to the predominant secondary stresses, the crack in the core spray line is expected to arrest prior to reaching 180°. An assessment was made to determine the critical flaw size of the core spray pipe by treating stresses associated with the design loading as primary stresses and performing a limit load evaluation. The results of this evaluation confirm that in the core spray lines a through-wall crack of up to 263° (approx. 11.5 inches) around the circumference would not cause pipe failure. This length is the maximum allowable crack lengths at the end of the next fuel cycle. If the observed length of the indication is less than this during future inspections, continued operation is justified. Using the crack growth rate of 5E-5 in/hr, the predicted time to reach the maximum allowable flaw size of 11.5 inches is 13 years.

3. REFERENCES

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3. DeSalvo, G. J., Ph.D. and Swanson, J. A., Ph.D., ANSYS Engineering Analysis System User's Manual, Revision 4.4, Swanson Analysis Systems, Inc., Houston, PA, May 1, 1989.

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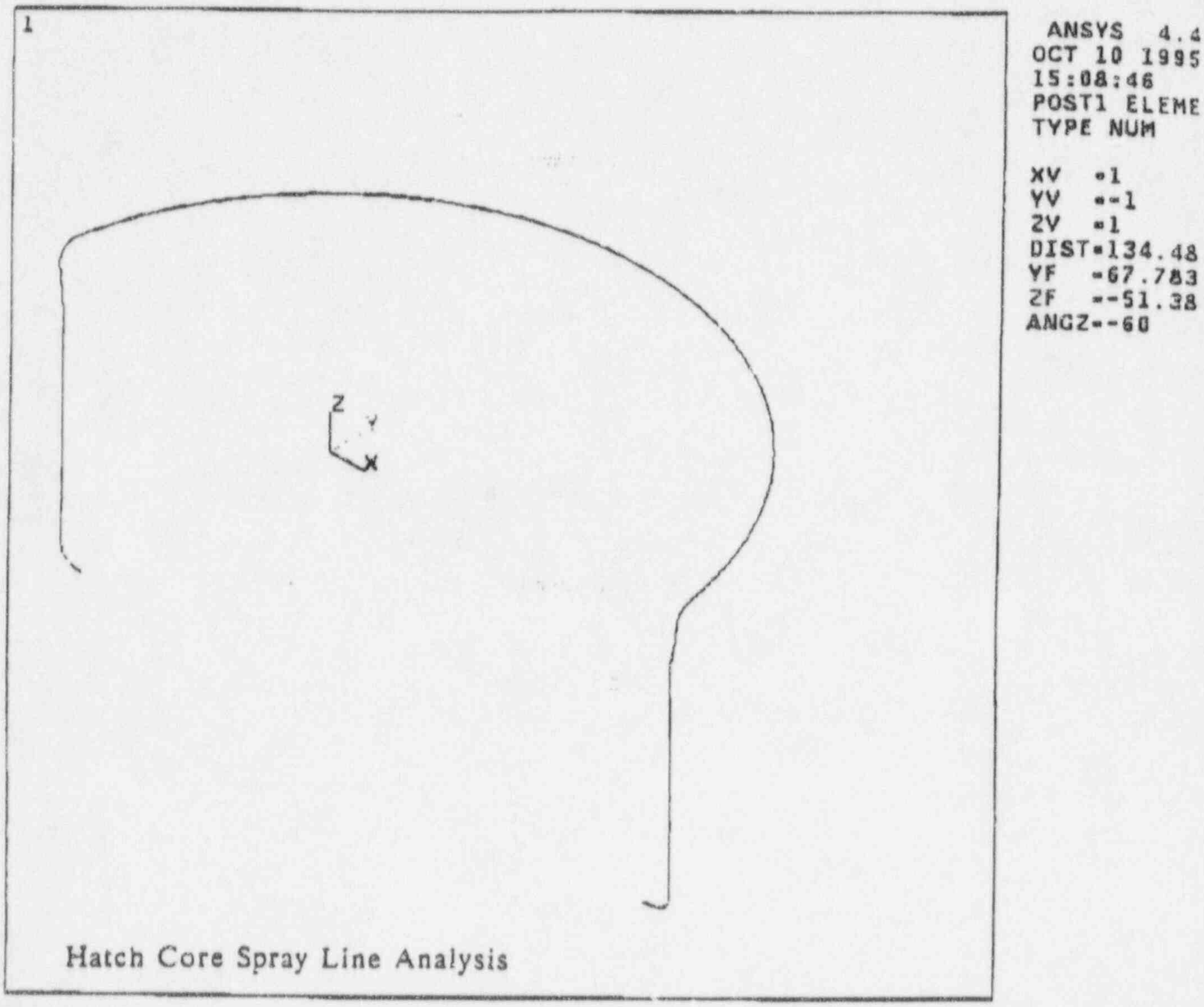

Figure 1 Finite Element Model of Core Spray System

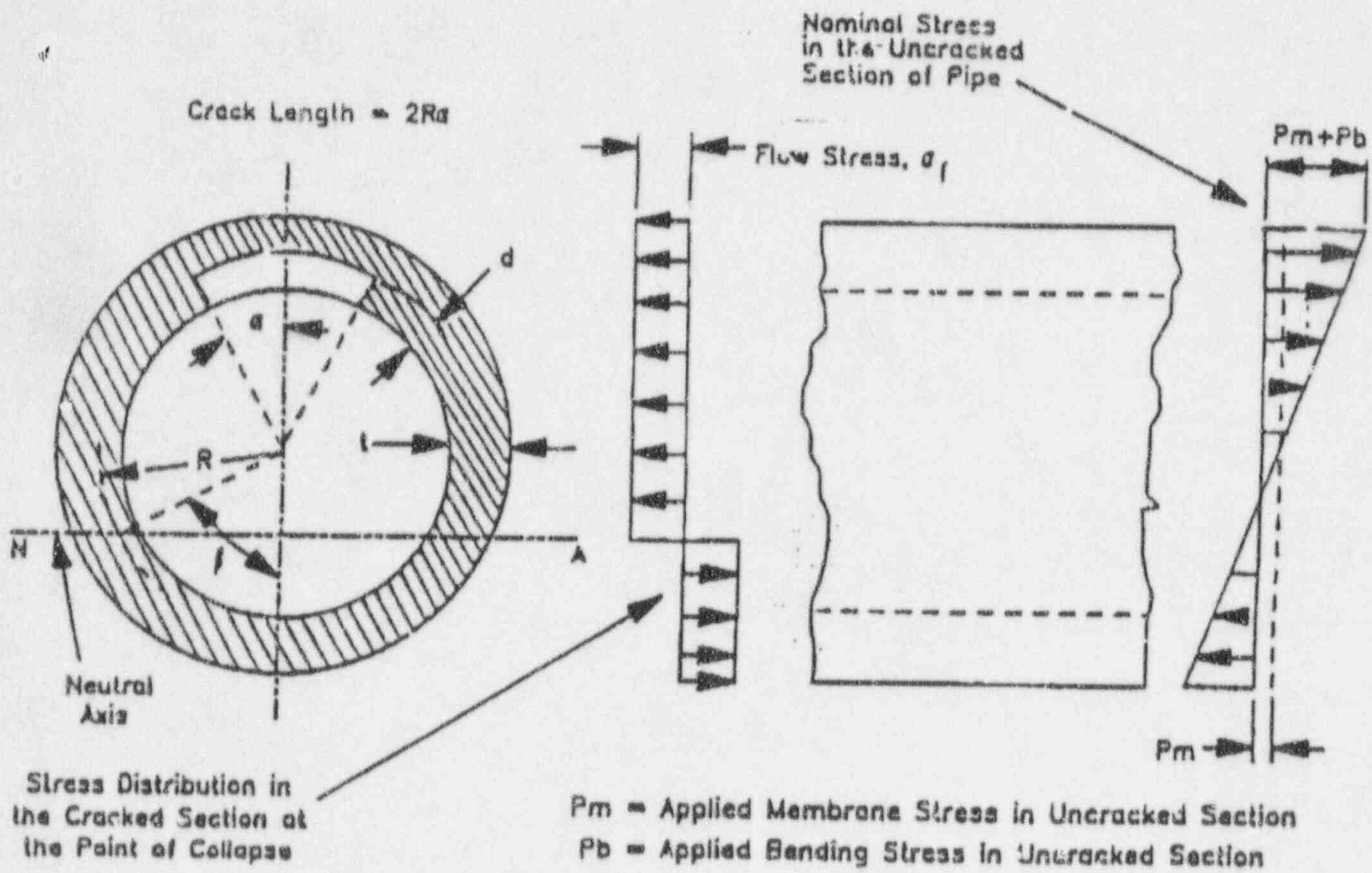

Figure 2 Stress Distribution in a Cracked Pipe at the Point of Collapse